MODULE R

MAINTENANCE RULE IMPLEMENTATION

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Maintenance Rule Implementation

- **Purpose: To acquaint students with ways in which PRA typically supports licensee implementation of the Maintenance Rule.**
- **Objectives:**
  - **Explain the purposes of the Maintenance Rule and identify areas in which PRA can support the rule's implementation**
  - **Explain how performance goals/criteria are established using the "EPRI Method"**
- **References:**
  - **10CFR50.65, Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants**
  - **Regulatory Guide 1.160, Monitoring the Effectiveness of Maintenance at Nuclear Power Plants**
  - **NUMARC 93-01, Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants**
  - **EPRI Technical Bulletin 96-11-01, "Monitoring Reliability for the Maintenance**
  - **EPRI Technical Bulletin 97-3-01**

Maintenance Rule Description

- Performance -Based Rule
- Effective July 10, 1996
- "To monitor the effectiveness of maintenance activities...
  - For safety-significant plant equipment...
  - In order to minimize the likelihood...
  - Of failures and events...
  - Caused by the lack of effective maintenance."

(Maintenance Rule Training Handouts)

Maintenance Rule Description

- **Paragraph (a)(1)**
  - Monitor performance of "problem" structures, systems, and components (SSCs)
  - Compare performance against goals
  - (a)(1) SSCs
- **Paragraph (a)(2)**
  - Reduced monitoring for SCCs meeting performance criteria
  - (a)(2) SSCs
- **Paragraph (a)(3)**
  - Periodically evaluate program
  - Incorporate industry-wide experience
  - Balance SSC unavailability and failures

Maintenance Rule Description

- Paragraph (a)(4)
  - Assess and manage increase in risk from maintenance activities
- Paragraph (b)
  - Scope of program
    - Safety-related SSCs
    - Non-safety-related SSCs
      - Mitigate accidents or are in plant Emergency Operating Procedures (EOPs)
      - Required for safety-related SSCs to work properly
      - Can cause a scram or actuation of safety-related SSC

Maintenance Rule History

- 1985: Davis Besse loss of all feedwater event
- 1985-86: Maintenance and Surveillance Program (MSP)
  - NUREG-1212, “Status of maintenance in the U.S. Nuclear Power Industry 1985,” June 1986
    - Found lack of performance trending, lack of risk consideration, and ineffective root cause correction actions
- 1988: Policy Statement on Maintenance of Nuclear Power Plants
- 1990: Process-oriented and performance-based rulemaking packages developed
- 1991: Performance-based rule adopted (5-year grace period)
- 1996: Rule implemented

Typical Maintenance Rule Implementation

- **Combination of traditional engineering analysis and PRA approaches**
  - **Reliance on expert panel to make final decisions**
- **Overall structure is performance-based approach**
- **Heavy reliance by most utilities on PRA support/information**

PRA Support for Maintenance Rule Implementation

- **Establishing safety significance of SSCs covered by rule**
- **Establishing performance criteria and goals [(a)(1), (a)(2)]**
- **Evaluating balancing of SSC unavailability and reliability [(a)(3)]**
- **Assessing impact on plant risk when SSCs are removed from service for maintenance [(a)(4)]**

Safety Significance of SSCs

- NUMARC 93-01 recommends use of three (3) importance measures
  - Core damage frequency (CDF) contribution, top 90% CDF minimal cut sets
  - Risk reduction worth (RRW), RRW ≥ 1.005
  - Risk achievement worth (RAW), RAW ≥ 2.0
- SSCs above cut-off levels for each importance measure are candidates for high safety significance
- Expert panel's role is also to consider and compensate for SSCs not in the PRA as well as PRA uncertainties...

Factors to be Considered in Use of PRA Importance Measures

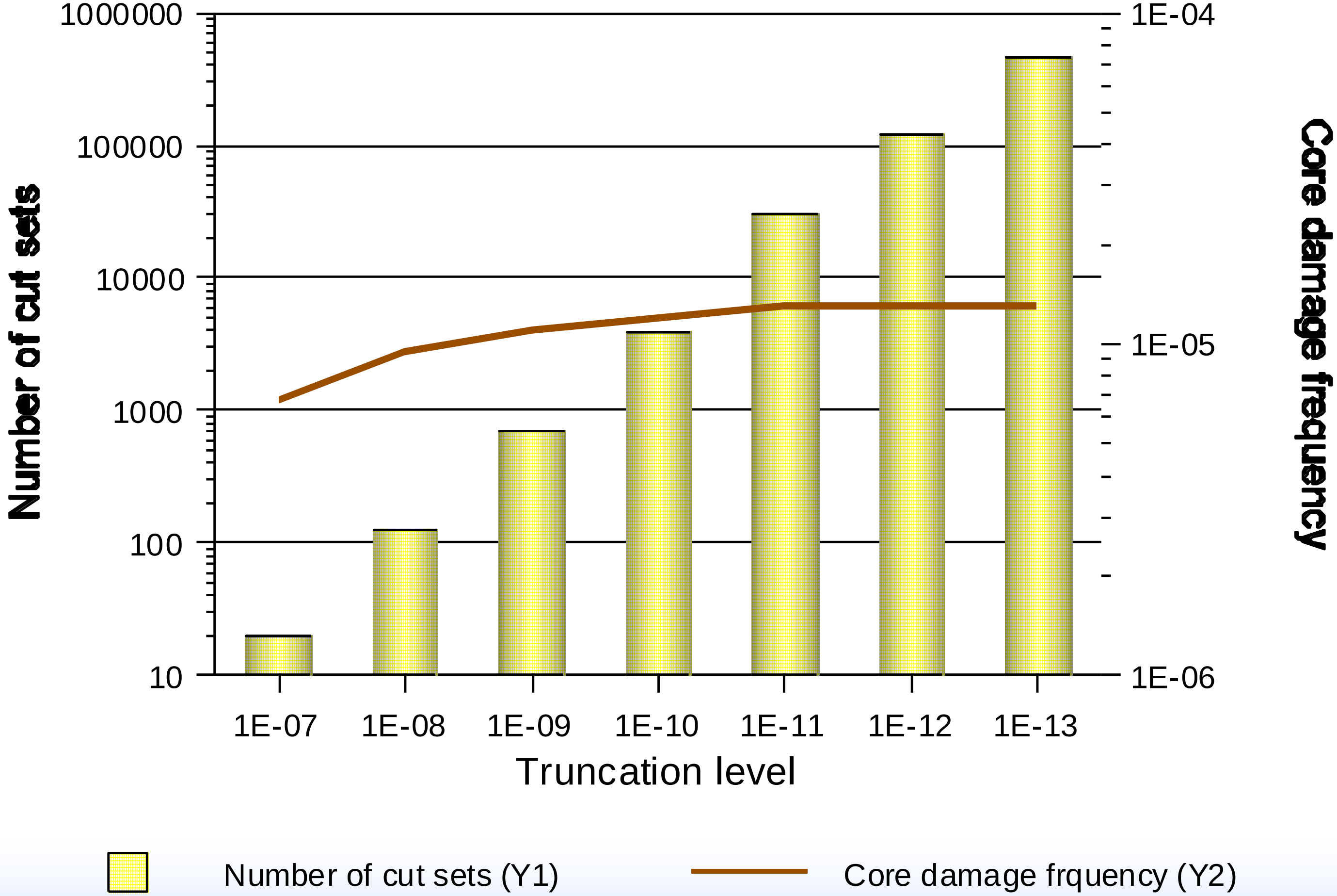
- **SSC importance vs PRA basic event importance**
  - **AFW Motor-driven pump A vs AFW-MDP-FS-A180**
- **Sequence truncation level used in PRA**
- **Core damage frequency importance vs large early release frequency importance**
- **Avoid reliance on just one measure of importance**

Some Relevant Statistics – Brunswick IPE

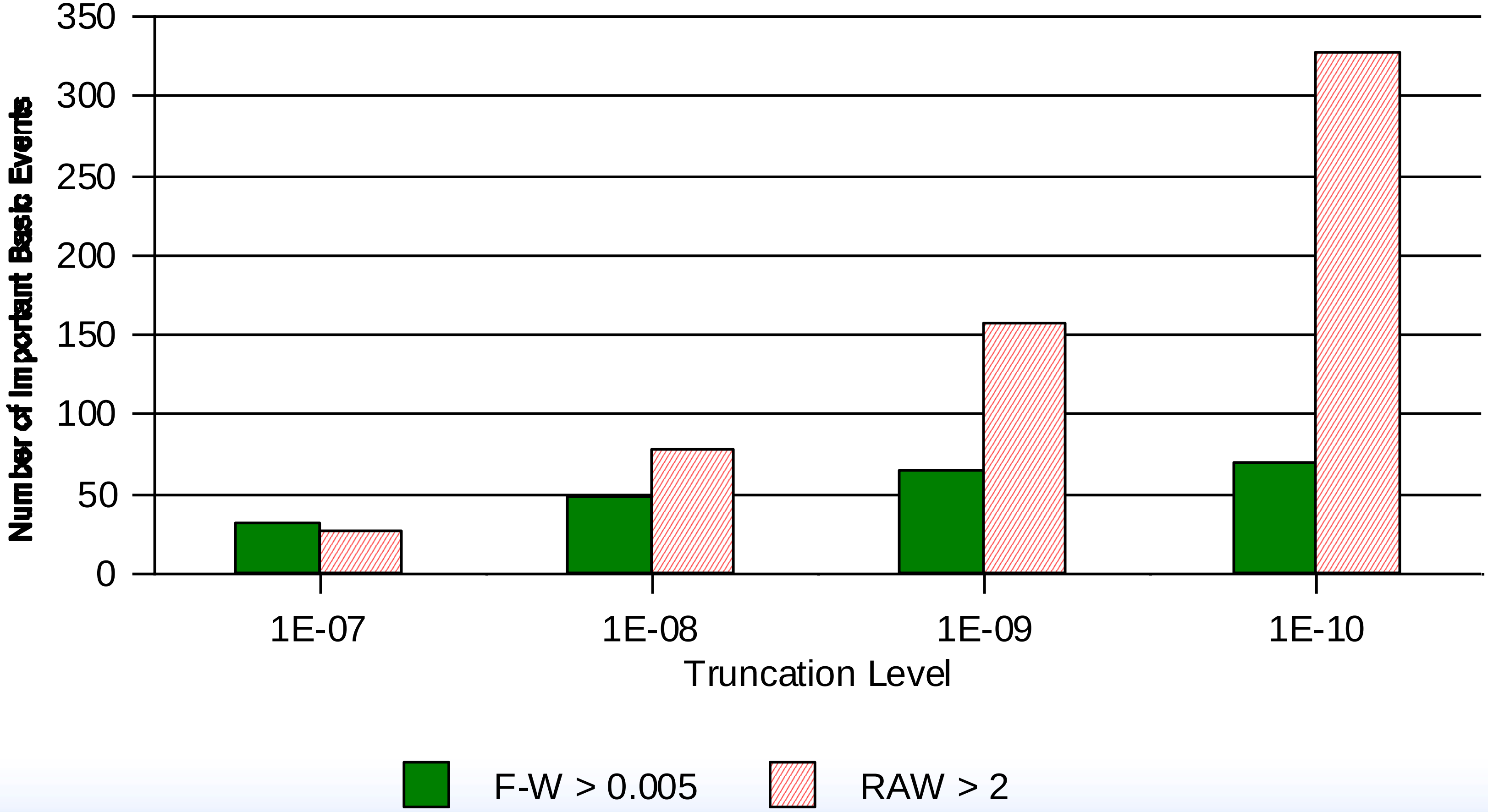
Truncation limit: 1E-10/yr
CDF: 6.34E-6/yr
No. basic events: 1543
No. events after truncation: 291
No. events w/F-V > 0.001: 150
No. events w/RAW > 2: 147

CDF Contribution	Top 90% Cutsets	Top 99% Cutsets
No. events in top cutsets	184	281
Highest F-V not included	0.00194	0.000133
Highest RAW not included	33.3	3.67
No. events w/F-V > 0.005 not included	0	0
No. events w/RAW > 2 not included	36	3

Core Damage Frequency and Number of Cut Sets Sensitive to Truncation Limits



Truncation Limits Affect Importance Rankings



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SSC Performance Criteria

- For high safety significance SSCs and standby low safety significance SSCs
  - Train-level unavailability and/or unreliability performance criteria
  - Unavailability measure - hours unavailable divided by hours plant was at power
  - Unreliability measure - number of failures over specified number of demands
- Implications of exceeding SSC performance criteria
  - SSCs become candidate for category (a)(1), criteria become goals to be met before SSC can be moved back to (a)(2)

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Unavailability Performance Criteria

- PRA information
  - Plant-specific historical data
    - Time period covered
  - Generic estimate
- Other information
  - System engineer's experience/judgement
  - Industry-wide experience
- Final choice
  - Plant-specific data
  - 95% of plant-specific data
  - Other

Unreliability Performance Criteria

- PRA information
  - Plant-specific historical data
    - Time period covered
  - Generic estimates often used
- Other information
- Final Choice
  - Generally 0, 1 or 2 failures over 2- to 3-year period
  - Relation to PRA values
    - Estimated or actual demands over 2- to 3-year period used to evaluate against value in PRA

Performance Criteria Expected to be Commensurate with Safety

- PRA values used to establish criteria - expectation is met
- If PRA values not used
  - Unavailability criteria
    - Sensitivity analysis if higher than PRA data
  - Unreliability criteria
    - EPRI approach
    - Sensitivity analysis
    - Others
- Acceptable increase in CDF/LERF not established by NRC
  - Not all SSCs expected to perform at limits

Methods for Establishing Reliability Goals/Criteria

- **EPRI method for reliability on demand (EPRI Technical Bulletin 96-11-01)**
  - **Assume failure probability in PRA/IPE is correct**
  - **Estimate number of demands over next evaluation period**
  - **Calculate number of failures using binomial distribution such that, if PRA value is correct, there is approximately a 5% chance of seeing more than that number of failure**

Methods for Establishing Reliability Goals/Criteria (cont.)

- **Example 1 – reliability on demand:**
  - **Probability of exactly x failures in 24 demands given p = 0.05 using Binomial**

    Pr(x = 0, given p = 0.05, N = 24) = 0.29

    Pr(x = 1, given p = 0.05, N = 24) = 0.37

    Pr(x = 2, given p = 0.05, n = 24) = 0.22

    Pr(x = 3, given p = 0.05, n = 24) = 0.09
  - **Probability of x failures in 24 demands given p = 0.05 using Binomial**

    Pr(x = 0, given p = 0.05, N = 24) = 0.29

    Pr(x $\leq$ 1, given p = 0.05, n = 24) = 0.29 + 0.37 = 0.66

    Pr(x $\leq$ 2, given p = 0.05, n = 24) = 0.29 + 0.37 + 0.22 = 0.88

    Pr(x $\leq$ 3, given p = 0.05, n = 24) = 0.29 + 0.37 + 0.22 + 0.09 = 0.97
- **Therefore, performance criterion could be set at 3 or fewer failures over the next evaluation period**
  - **A conservative approach would be to set performance criterion of 2 or fewer failures over the next evaluation period**

Methods for Establishing Reliability Goals/Criteria (cont.)

- **Example 2 – reliability on demand:**
  - **Probability of exactly x failures in 30 demands given p = 0.01 using Binomial**

    $Pr(x = 0, \text{ given } p = 0.01, N = 30) = 0.74$

    $Pr(x = 1, \text{ given } p = 0.01, N = 30) = 0.22$

  - **Probability of x failures in 30 demands given p = 0.01 using Binomial**

    $Pr(x = 0, \text{ given } p = 0.01, N = 30) = 0.74$

    $Pr(x \leq 1, \text{ given } p = 0.01, N = 30) = 0.74 + 0.22 = 0.96$

- **Therefore, performance criterion could be set at 1 or fewer failures over the next evaluation period**
  - **A conservative approach would be to set performance criterion of 0 failures over the next evaluation period**

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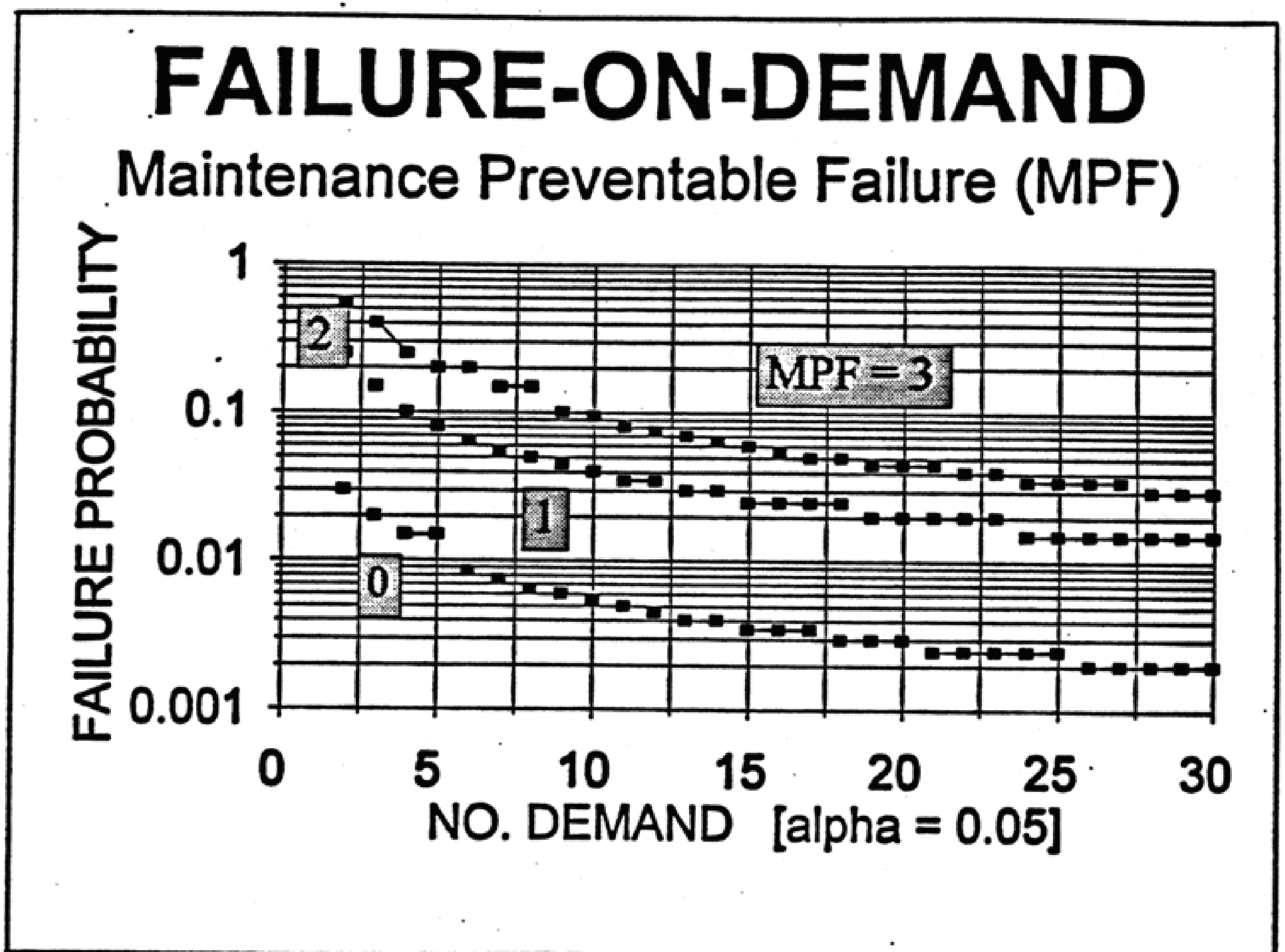
FIGURE 2



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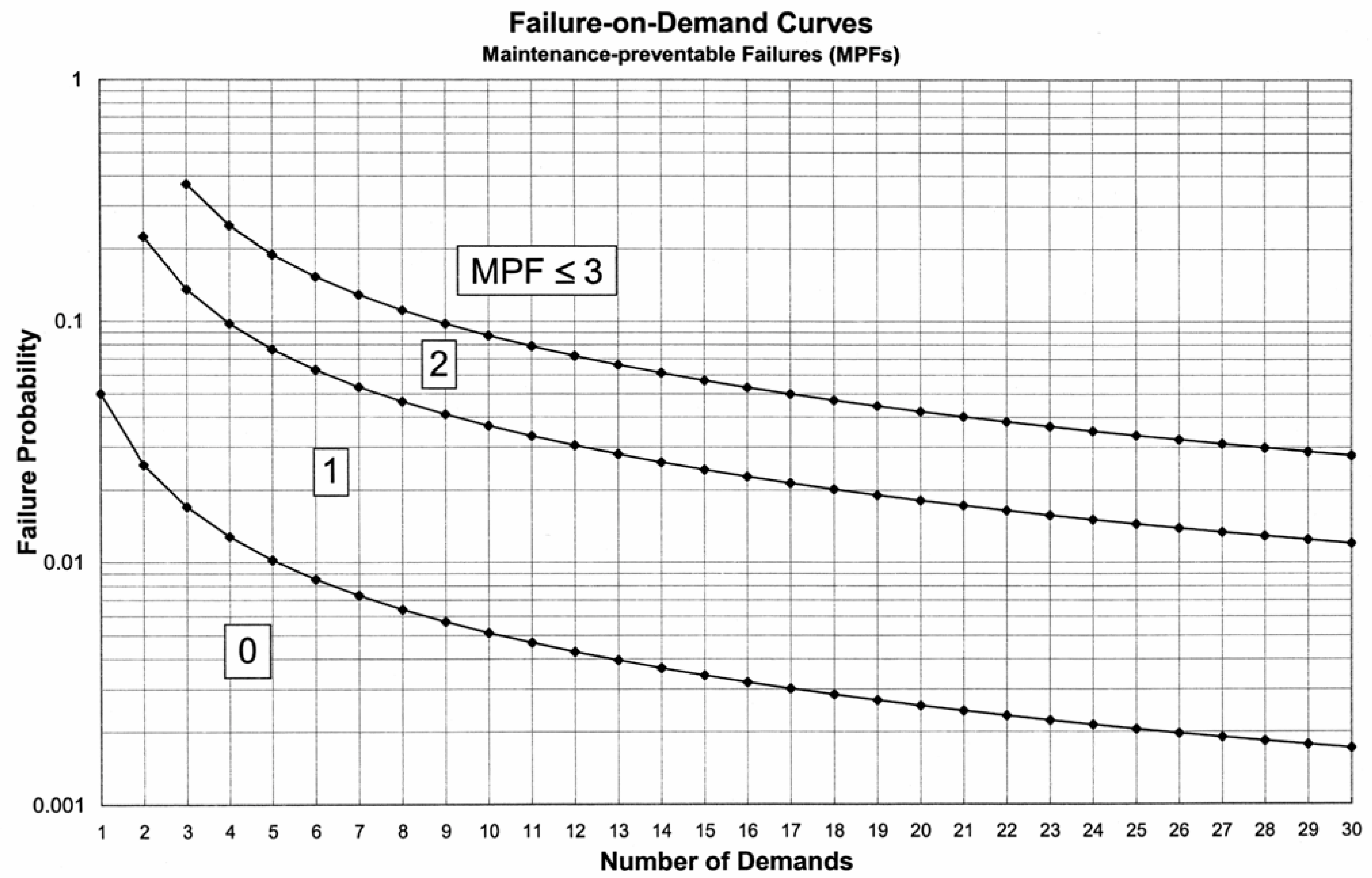

Failure-on-Demand Curves
Maintenance-preventable Failures (MPFs)
Failure Probability
1
0.1
0.01
0.001
MPF ≤ 3
2
1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Number of Demands

Methods for Establishing Reliability Goals/Criteria (cont.)

- **EPRI method for reliability of normally running SSCs (EPRI Technical Bulletin 97-3-01)**
  - **Assume failure rate in PRA/IPE is correct**
  - **Estimate total running time over next evaluation period**
  - **Calculate number of failures, using Poisson distribution, such that, if PRA value is correct, there is approximately a 5% chance of seeing more than that number of failures**

Methods for Establishing Reliability Goals/Criteria (cont.)

- **Example 3 – reliability on normally running:**
  - Probability of exactly x failures in 10,000 hours given that the failure rate (λ) = 5x10-5/hour using Poisson

    Pr(x = 0, given λ = 5x10-5/hour, t = 10,000 hrs) = 0.61

    Pr(x = 1, given λ = 5x10-5/hour, t = 10,000 hrs) = 0.30

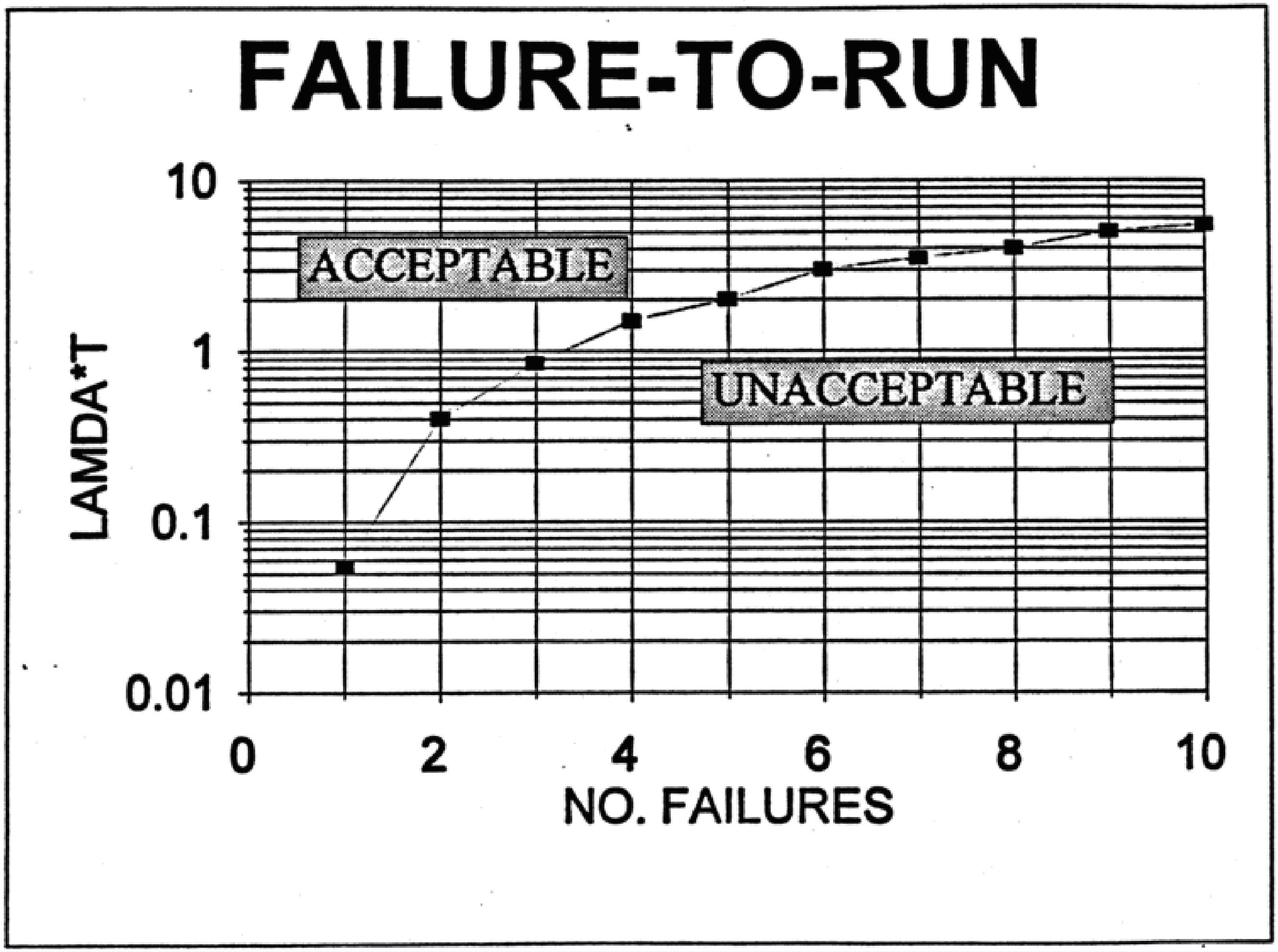
    Pr(x = 2, given λ = 5x10-5/hour, t = 10,000 hrs) = 0.08
  - Probability of x failures in 10,000 hours given that the failure rate (λ) = 5x10-5/hour using Poisson

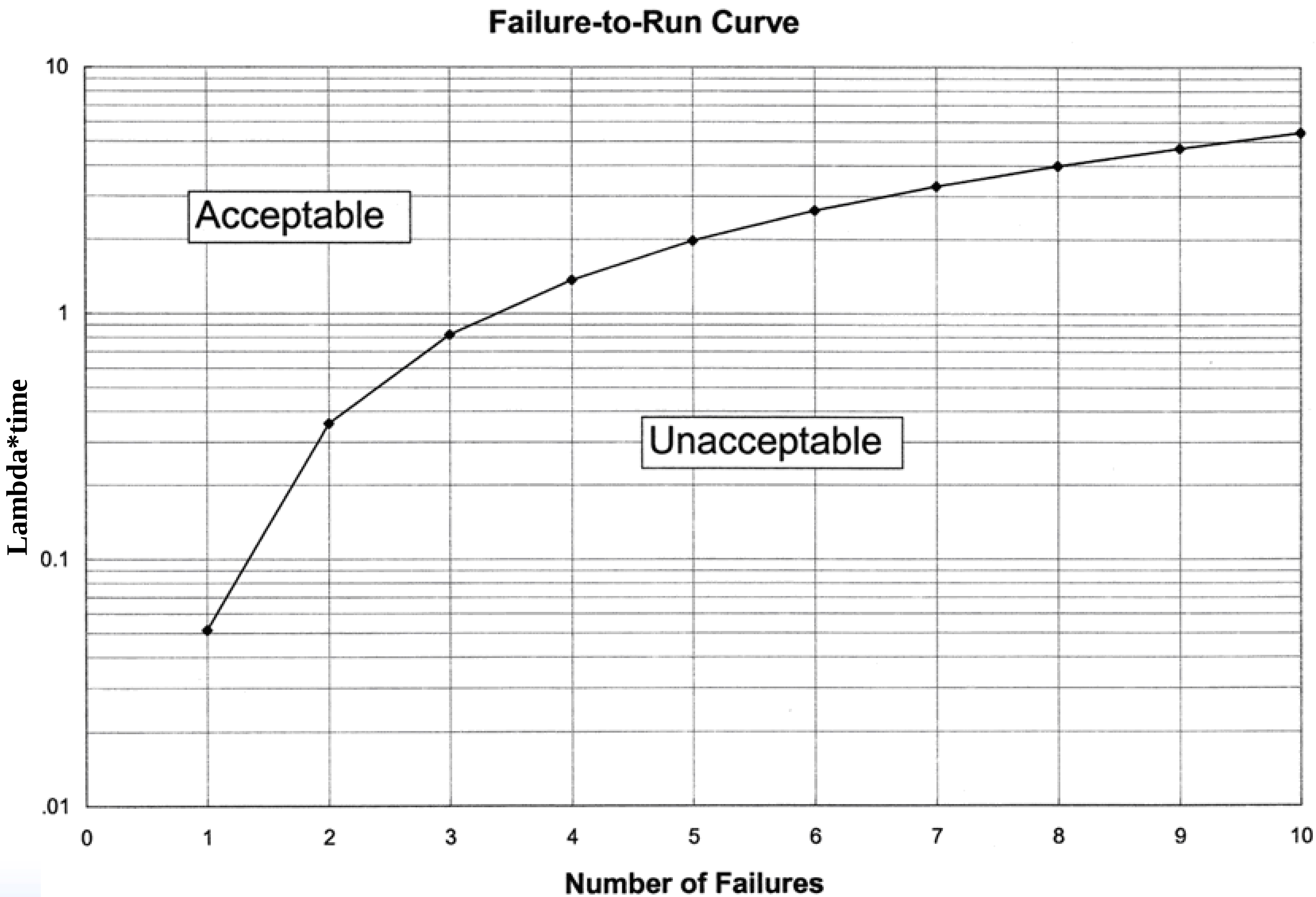
    Pr(x = 0, given λ = 5x10-5/hour, t = 10,000 hrs) = 0.61

    Pr(x ≤ 1, given λ = 5x10-5/hour, t = 10,000 hrs) = 0.91

    Pr(x ≤ 2, given λ = 5x10-5/hour, t = 10,000 hrs) = 0.99
- **Therefore, performance criterion could be set at 2 or fewer failures over the next evaluation period**
  - A conservative approach would be to set performance criterion at 1 or fewer failures over the next evaluation period

FIGURE 3


FAILURE-TO-RUN
10
1
0.1
0.01
LAMDA*T
ACCEPTABLE
UNACCEPTABLE
0
2
4
6
8
10
NO. FAILURES



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Balancing of Unavailability and Unreliability

- **Track SSC unavailability and unreliability**
- **Compare with performance criteria**
- **If performance criteria are approached or exceeded**
  - **Reduce preventive maintenance (if unavailability criterion is exceeded with no failures)**
  - **Increase preventive maintenance (if failure criterion is exceeded with low unavailability)**

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Assessing Plant Risk From Maintenance

- Configuration management
  - Work week schedule guidance
    - 12-week rolling schedule
    - Days of week schedule for SSCs
    - Plant risk matrix or plant status monitor required by Maintenance Rule
    - Operator experience/judgment

Plant Risk Matrix

- **Goal-Assess plant risk given all planned/unplanned SSC maintenance outages**
- **Originally was at least a 2-dimensional matrix covering high safety significance SSC maintenance outages**
  - **PRA based**
  - **Yes or no for planned outages of 2 SSCs, based on PRA estimate of plant risk**
  - **Guidance for 3 or more planned SSC outages**
- **Consideration of emergent failures**

Plant Risk Matrix

Diesel Generator 1	Diesel Generator 2	HPCI	RCIC	Control Rod Drive Hydraulic
DGI	No	Yes*	Yes*	Yes*
	DG2	Yes*	Yes*	Yes
		HPCI	No	No
			RCIC	No

No - High plant risk
Yes - Low plant risk
* Time limitation applies

For Additional Information

- **Maintenance Rule Implementation Inspection Reports (for plants already inspected)**
- **NUREG-1526, Lessons Learned from Early Implementation of the Maintenance Rule at Nine Nuclear Power Plants**
- **Maintenance Rule Guideline Book**